



## GEOLOGIC RESOURCE MONITORING PARAMETERS

# Dune Formation and Reactivation



**Brief Description:** Dunes and sand sheets develop under a range of climatic and environmental controls, including wind speed and direction, and moisture and sediment availability. In the case of coastal dunes, sea-level change and beach and nearshore conditions are important factors. Organized dune systems and sheets in continental environments form from sediment transported or remobilized by wind action. New generations of dunes may form from sediment remobilized by climatic change and/or human disturbances. Dune formation and movement is well documented from the margins of many deserts, as well as from temperate regions and along sandy coasts [see shoreline position]. Sand movement is inhibited by moisture and vegetation cover, so that dunes can also be used as an indicator of near-surface moisture conditions. Changes in dune morphology or position may indicate variations in aridity, wind velocity and direction [see wind erosion], or disturbance by humans. Dune changes can be correlated with climatic variables using aridity indices and the dune mobility index, which is the ratio between available wind energy and the precipitation-potential evapotranspiration ratio.

**Significance:** Moving dunes may engulf houses, fields, settlements and transportation corridors. Active dunes in sub-humid to semi-arid regions decrease arable land for grazing and agriculture. They also provide a good index of changes in aridity. Coastal dunes are important determinants of coastal stability, supplying, storing and receiving sand blown from adjacent beaches. Dunes play an important role in many ecosystems (boreal, semi-arid, desert, coastal) by providing morphological and hydrological controls on biological gradients.

**Environment where Applicable:** Sand dunes occur widely - in deserts, in tropical and sub-tropical latitudes, semi-arid continental mid-latitude regions. They also occur along sandy ocean beaches, estuaries and lake shorelines from the Arctic to the Equator.

**Types of Monitoring Sites:** Margins of active dune areas. Sand hills and vegetation-stabilized dunes in mid-continental areas, ideally located along climatic transects.

**Method of Measurement:** Changes in size, shape and position of sand sheets and dune fields can be monitored by repeated ground surveys and measurement of active and dormant/relict dunes, by air photos, or by satellite images.

**Frequency of Measurement:** Dune systems should be monitored every 5-10 years to observe changes associated with drought cycles, more frequently when movement is detected.

**Limitations of Data And Monitoring:** Climatic records, especially wind data, are commonly lacking.

**Possible Thresholds:** Dune mobility index  $M > 50$ , where M is the ratio between (1) the percentage of the time the wind blows above about 5 m/sec (the threshold velocity for sand transport), and (2) annual rainfall divided by potential transpiration. Other thresholds could be based on acceptable limits for active dune areas on agricultural land, as well as on associated groundwater levels.

### Key References:

Berger, A.R. & W.J.Iams (eds). Geoindicators: Assessing rapid environmental changes in earth systems. Rotterdam: A.A. Balkema. (Papers by Vance & Wolfe and Lancaster).

Cooke, R., A.Warren & A.Goudie 1993. Desert geomorphology. London, UCL Press.

McKee, E.D. 1979. A study of global sand seas. U.S. Geological Survey Professional Paper 1052.

Muhs, D.R. & V.T.Holliday 1995. Active dune sand on the Great Plains in the 19th Century: evidence from accounts of early explorers. *Quaternary Research* 43: 118-124.

Nordstrom, K.F., N.Psuty & B.Carter 1990. Coastal dunes: form and process. Chichester, John Wiley and Sons.

**Related Environmental and Geological Issues:** Mobile dunes may invade and destroy productive agricultural land and affect transportation routes. Human efforts to stabilize dunes commonly fail because they introduce disequilibrium structures that run counter to natural trends. Many efforts have been made to stabilize dunes, especially in coastal complexes by planting sand-binding vegetation. Dune migration may affect shallow water table levels by reducing surface evaporation.

**Overall Assessment:** Dunes are very important indicators of environmental change in arid and semi-arid regions and coastal zones.

**Source:** This summary of monitoring parameters has been adapted from the Geoindicator Checklist developed by the International Union of Geological Sciences through its Commission on Geological Sciences for Environmental Planning. Geoindicators include 27 earth system processes and phenomena that are liable to change in less than a century in magnitude, direction, or rate to an extent that may be significant for environmental sustainability and ecological health. Geoindicators were developed as tools to assist in integrated assessments of natural environments and ecosystems, as well as for state-of-the-environment reporting. Some general references useful for many geoindicators are listed here:

Berger, A.R. & W.J.Iams (eds.) 1996. *Geoindicators: assessing rapid environmental change in earth systems*. Rotterdam: Balkema. The scientific and policy background to geoindicators, including the first formal publication of the geoindicator checklist.

Goudie, A. 1990. *Geomorphological techniques*. Second Edition. London: Allen & Unwin. A comprehensive review of techniques that have been employed in studies of drainage basins, rivers, hillslopes, glaciers and other landforms.

Gregory, K.J. & D.E.Walling (eds) 1987. *Human activity and environmental processes*. New York: John Wiley. Precipitation; hydrological, coastal and ocean processes; lacustrine systems; slopes and weathering; river channels; permafrost; land subsidence; soil profiles, erosion and conservation; impacts on vegetation and animals; desertification.

Nuhfer, E.B., R.J.Proctor & P.H.Moser 1993. *The citizens' guide to geologic hazards*. American Institute for Professional Geologists (7828 Vance Drive, Ste 103, Arvada CO 80003, USA). A very useful summary of a wide range of natural hazards.